**Popular science summary**

Contemporary technology development leading to the creation of many modern devices is the reason for the constantly growing demand for modern materials exhibiting reduced weight while increasing strength and resistance to all kinds of external factors. In this area, additively manufactured (AM) materials becoming the promising alternative for commercial ones, as they are designed taking into account the functionality of the components, their appropriate selection, expected restrictions in operation and the optimization of many their features to meet the objective function assumed. Furthermore, Additive Manufacturing technologies offers many advantages over more traditional manufacturing technologies. The ability to selectively deposit materials only where they are needed means that parts can be much more complex in design, and lighter weight, which can dramatically improve performance. The process is toolless, and so ideally suited for one-off or personalised products, unlike processes such as mechanical machining, casting and injection molding that require significant up-front investment in tooling, with little ability to iterate product designs or provide any product differentiation. For the above-mentioned reasons, in the proposed project it is planned to conduct experimental and numerical analysis of mechanical properties and resistance to damage of Inconel 718, Inconel 625 and Ti5553 manufactured by using Laser Engineered Net Shaping (LENS) technology. The main goal of the project is to recognize the physical mechanisms responsible for the process of plastic deformation induced by complex loadings. It is commonly know, that just the complex loadings are the most effective and most faithful ways that may reflect the real working conditions of the material used for specific structural elements. The materials to be investigated will be tested in the as-built state and after deformation history induced deliberately by monotonic loading or low cycle fatigue processes. In order to effectively visualize changes in the stress state of the tested materials subjected to the loading history defined, the concept of yield surface will be used. It is defined as the geometrical place of points in the stress space corresponding to the same value of strain. Two unique complementary testing systems will be used for the characterization of mechanical properties and damage evolution: a testing machine for simultaneous loading of thin-walled tubular specimens by means of axial force, torque and internal pressure, and a modern machine for material testing on cruciform specimens, ensuring the implementation of tests in a plane stress state resulting from simultaneous action of axial forces in two mutually perpendicular directions. This combination of testing machines guarantees the unique possibilities for material properties assessments. In addition, digital image correlation (DIC) will be used for identification specimen damage initiation and its further development, particularly in the area of cyclic loading. Application of optical system in the case of tests on the cruciform testing machine will give the great opportunity to compare their capabilities in terms of accuracy of the results and resolution of methods. An important component of the research will be results from tests in which a combination of monotonically increasing load with symmetrical cycles will be applied. This type of research will be carried out on both types of specimens. Some results of the preliminary tests on the tubular specimens show significant reductions in tensile strength as long as torsional cycles accompany it. Confirmation of this type of effect on the cruciform specimens may have potentially an important significance for future more effective design of different technological processes. The last important aim of the project is related to modelling of the deformation mechanisms and degradation processes associated with the local stress-strain evolution. Finite element method (FEM) will be used to simulate the low-cycle behaviour of AM materials. Among general steps and considerations for modelling one can indicate: definition of the material properties; choosing a suitable modeling approach; determination of the microstructural representation; incorporation of constitutive equations; implementation of boundary and loading conditions; validation and calibration of the model; evaluation of local stress-strain evolution; iteration and refinement of the model. By following these steps and continually refining the model, researchers can gain insights into the deformation mechanisms and degradation processes associated with the local stress-strain evolution. These models can provide a deeper understanding of the material behavior and aid in the development of materials with enhanced properties or in the optimization of structural designs.